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ANNUAL VARIABILITY RAINFALL MAPS FOR NEBRASKA

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[University of Nebraska, Lincoln, Nebr., March 1935]

INTRODUCTION

In irrigated areas where the required amount of water for crop production is always available, little attention need be paid locally to precipitation. For this reason the routine of farm management may take on a measure of precision that is seldom possible in areas dependent directly upon rainfall with its uncertainties. There is little, if any, land in Nebraska where crop production is not intimately affected by rainfall variability. Those years with low rainfall are, as a rule, not so favorable to the growth of economic plants as are the years with medium or high rainfall.

Since the element of chance is nearly always a factor that the farmer must consider, he is interested especially in knowing approximately what the chances are. He always wants to reduce the chance elements, and increase the elements of certainty. Since rainfall is a variable element, he is interested in knowing not only when his chances for a given amount are even, or 50–50, but also for what farm operations he may expect the chances for the needed amount of rainfall to be 2 to 1, or 5 to 1, in his favor. If he is acquainted with the relative proportion of the chance elements as far as rainfall is concerned, he may plan accordingly and thus succeed in his farm operations a larger proportion of the time. For instance, if it is known that a certain crop seldom succeeds with an annual rainfall of less than 20 inches, then the farmer wants to know what proportion of the time he may expect the precipitation to be up to or above this minimum. If the past record indicates a ratio of 10 to 1 for the minimum amount of rainfall, he might feel much safer in proceeding with proposed plans than if the chances were only 2 to 1.[1]

THE PURPOSE OF THE STUDY

To the average individual, an isohyetal map of the mean annual rainfall of an area probably indicates approximately the amount of precipitation or more that may be expected 50 percent of the time; this view, however, is in error. In reality the rainfall more often falls below the mean than above it. For this reason, the mean as a measure of central tendency is not as satisfactory as the median. The mean annual rainfall for Lincoln, Nebr., calculated from a 56-year record, is 27.82 inches. During this period the annual precipitation has been above the mean 24 times and below 32 times. The median rainfall for Lincoln is 26.50 inches and, of course, 28 times above and 28 times below this amount. To anyone who is interested in the dependability of rainfall, it is at once apparent that the median of 26.50 inches, or 1.32 inches less than the mean, represents the amount that has actually fallen 50 percent or more of the time, or 50 percent or less of the time. When the 56 years of precipitation at Lincoln are arranged in a volume sequence it is a simple matter to find the amount of rainfall such that this amount or more has fallen any desired percentage of the time.

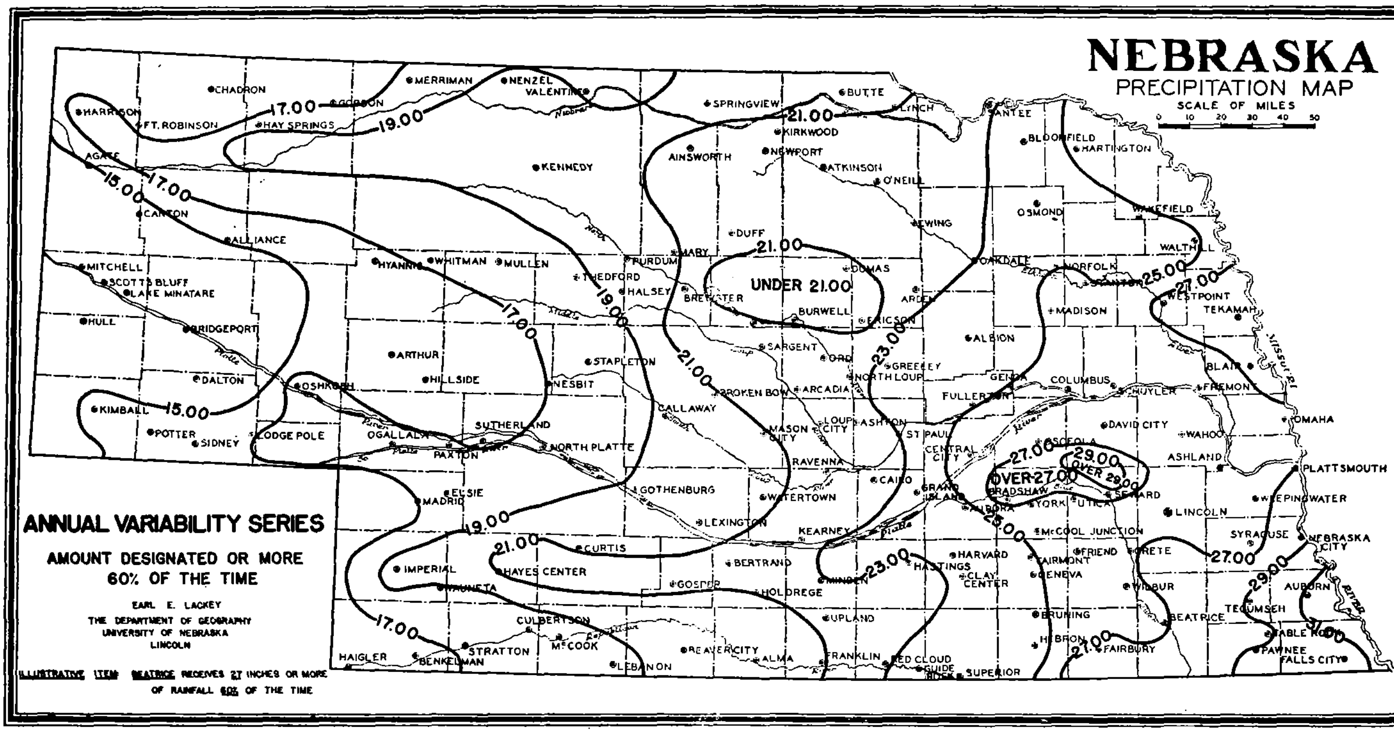
The purpose of this study is to construct a series of rainfall maps for Nebraska on the isohyets of which is indicated the amount of rainfall or more that has fallen 20, 40, 50, 60, and 80 percent of the time, respectively (figures 1, 2, 3). The data basic to the series are the actual amounts of precipitation received year by year for each of the stations within the State where the record has been kept. In only 7 of the 109 stations is the record shorter than 20 years. The average period of observation is 37 years.

RAINFALL VARIABILITY

If the record for each of the stations ran 100 years the obtained median would be nearer the true median. Were a record of 1,000 years available the obtained median and percentile amounts would be still nearer the true ones. Since long-time records are not available, the obtained medians and percentile amounts are assumed to approximate the true figures. It is on this assumption that the data are statistically treated for the construction of the annual variability series of isohyetal maps explained in this paper.

Rainfall variability is usually expressed in terms of departure from the normal (mean). However, the median annual rainfall is lower than the mean at 96 of the 109 stations in Nebraska—averaging 1.08 inches below for the 109 stations. At 13 stations out of the 109 the median is higher than the mean—averaging 0.43 inches above for the 13 stations. For the 109 stations the medians average 0.90 inches below the mean. For the purposes of this study, therefore, the variability is expressed in percentile amounts. Thus, for Lincoln with a 56-year record, 34.17 inches or more of precipitation have fallen 20 percent of the time, 28.05 inches or more 60 percent of the time, and 22.28 inches or more 80 percent of the time (table 1). Corresponding data from 109 stations in Nebraska were used in the construction of the annual variability series of isohyetal maps (figures 1, 2, and 3).

[1] Blair, T. A., *Partial Correlation Applied to Dakota Data on Weather and Wheat Yield*, MONTHLY WEATHER REVIEW, February 1918; *Rainfall and Spring Wheat*, MONTHLY WEATHER REVIEW, October 1913.


NEBRASKA
PRECIPITATION MAP
SCALE OF MILES
0 10 20 30 40 50
ANNUAL VARIABILITY SERIES
AMOUNT DESIGNATED OR MORE
60% OF THE TIME
EARL E. LACKEY
THE DEPARTMENT OF GEOGRAPHY
UNIVERSITY OF NEBRASKA
LINCOLN
ILLUSTRATIVE ITEM: BEATRICE RECEIVES 27 INCHES OR MORE OF RAINFALL 60% OF THE TIME
UNDER 21.00
OVER 27.00
OVER 29.00

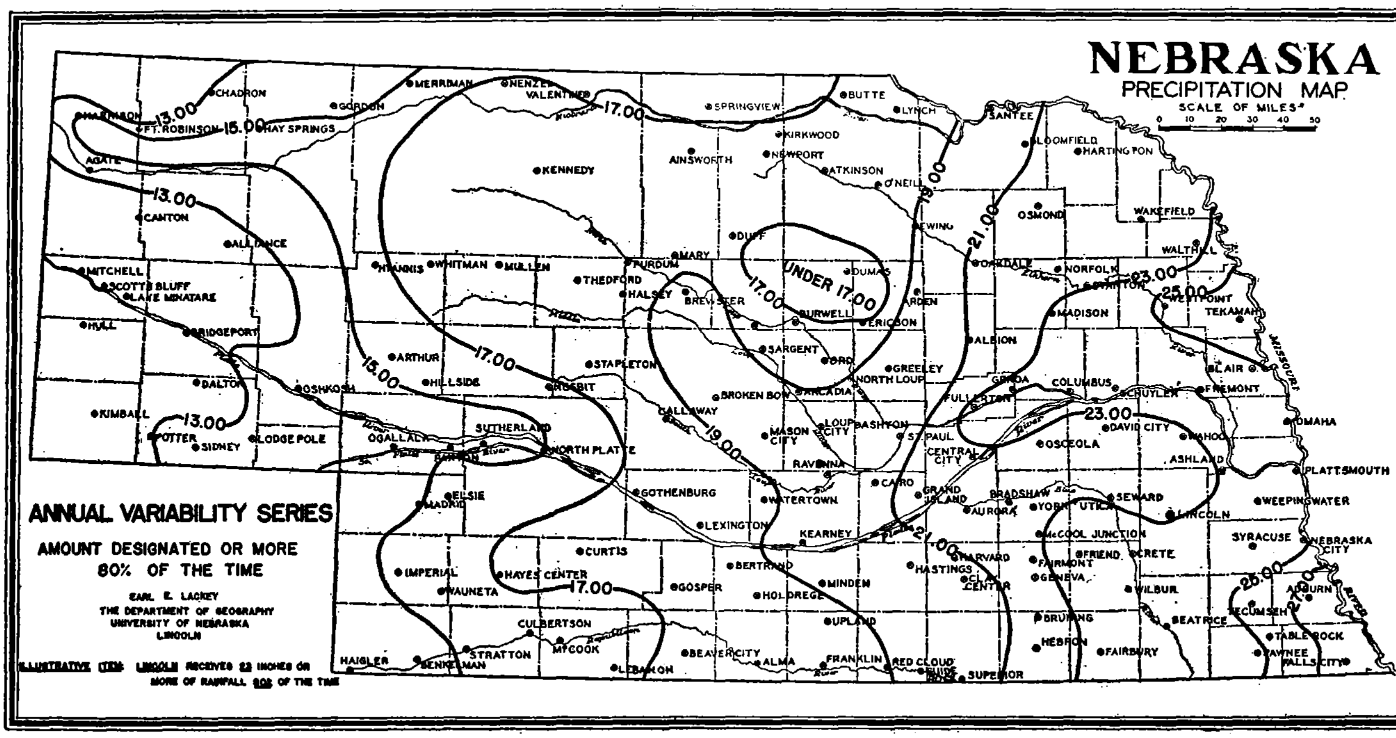
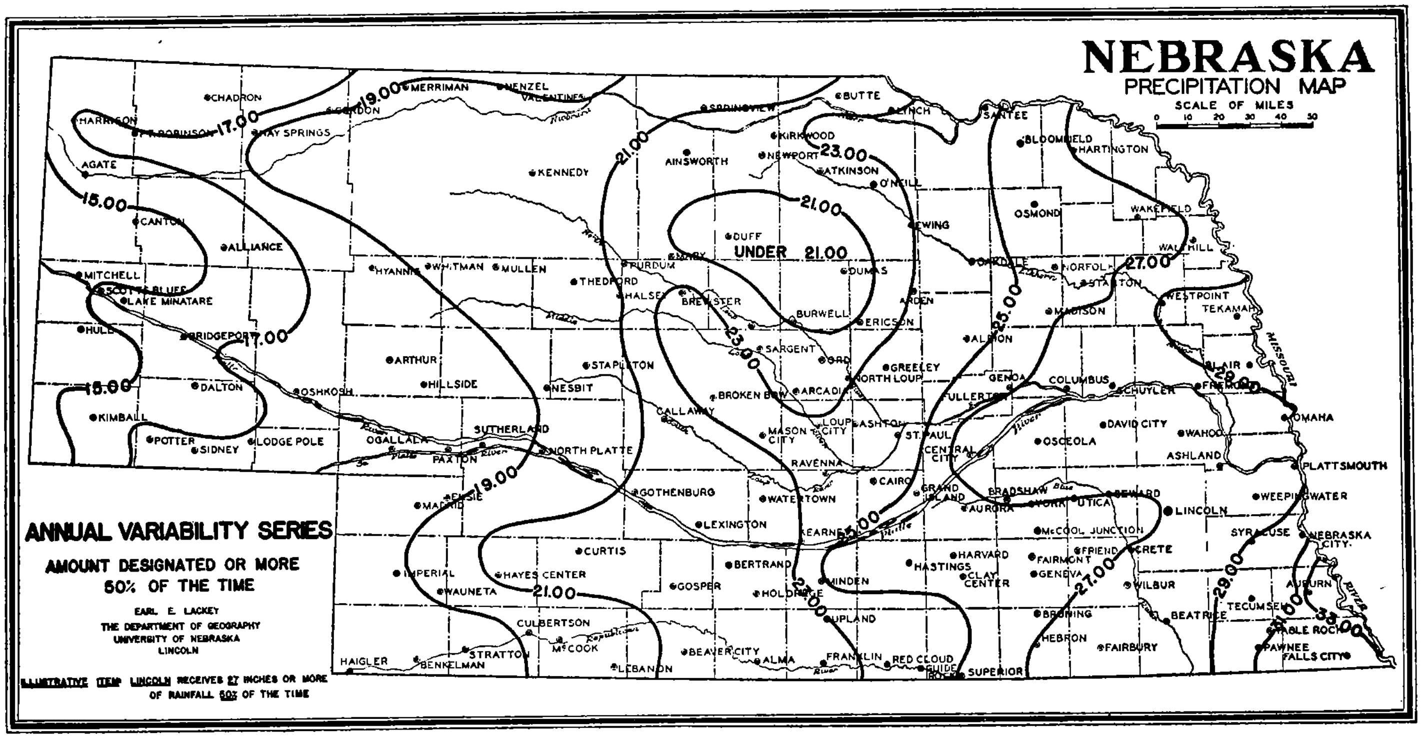

NEBRASKA
PRECIPITATION MAP
SCALE OF MILES
0 10 20 30 40 50
ANNUAL VARIABILITY SERIES
AMOUNT DESIGNATED OR MORE
80% OF THE TIME
EARL E. LACKEY
THE DEPARTMENT OF GEOGRAPHY
UNIVERSITY OF NEBRASKA
LINCOLN
UNDER 17.00

FIGURE 1.


NEBRASKA
PRECIPITATION MAP
SCALE OF MILES
ANNUAL VARIABILITY SERIES
AMOUNT DESIGNATED OR MORE
50% OF THE TIME
EARL E. LACKEY
THE DEPARTMENT OF GEOGRAPHY
UNIVERSITY OF NEBRASKA
LINCOLN
ILLUSTRATIVE ITEM: LINCOLN RECEIVES 27 INCHES OR MORE OF RAINFALL 50% OF THE TIME
UNDER 21.00

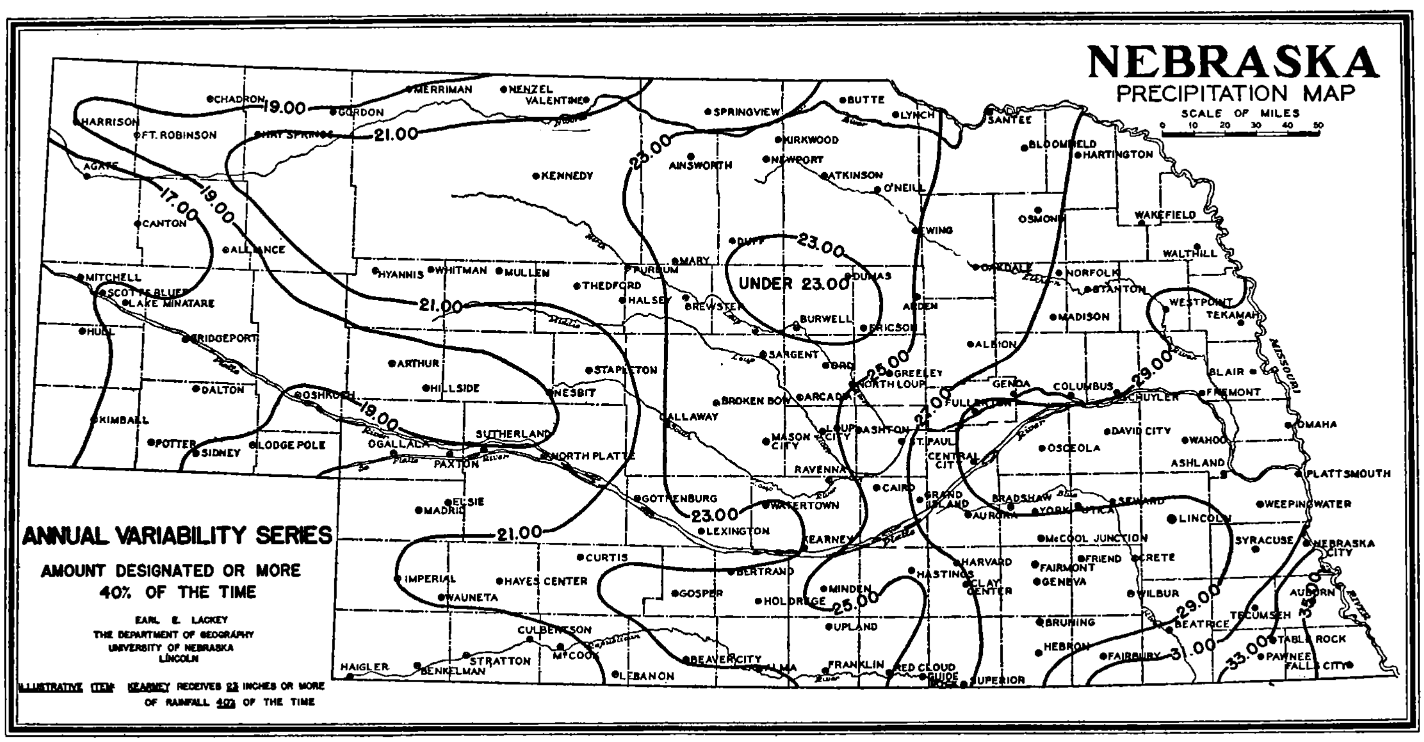

NEBRASKA
PRECIPITATION MAP
SCALE OF MILES
ANNUAL VARIABILITY SERIES
AMOUNT DESIGNATED OR MORE
40% OF THE TIME
EARL E. LACKEY
THE DEPARTMENT OF GEOGRAPHY
UNIVERSITY OF NEBRASKA
LINCOLN
ILLUSTRATIVE ITEM: KEARNEY RECEIVES 23 INCHES OR MORE OF RAINFALL 40% OF THE TIME
UNDER 23.00

FIGURE 2.

DIFFERENCES IN VARIABILITY

Stations with practically the same median rainfall, and approximately the same number of yearly records, may differ widely in variability. For example, Crete according to a 54-year record has a median of 27.18 inches with a quartile deviation [2] of 3.6 inches, while Fairbury according to a 58-year record has received 27.96 inches with a quartile deviation of 4.1 inches (table 1). The results of this difference are shown in figure 4. The medians are almost identical, yet according to the record Crete has received 23.24 inches or more 80 percent of the time, while Fairbury has received 24.13 inches or more 80 percent of the time—a difference of 0.89 of an inch.

Stations with about the same length of record but differing amounts of rainfall may have nearly the same quartile deviation. For example, Crete and North Platte have 54- and 59-year records, respectively, and corresponding quartile deviations of 3.6 and 3.7 inches (table 1). The former has a median annual rainfall of 27.18 inches and the latter 17.95 inches (fig. 4). This signifies that the variability at North Platte is much greater than that at Crete, since the quartile deviation at the former is 21 percent of the median, while at the latter it is 13 percent.

Thus, it is seen that departure or spread as expressed by the quartile deviation is just as important as the median annual rainfall. As far as departure from the median is concerned, farming is more precarious at North Platte than at Crete because the rainfall is not only less, but it is less dependable, and therefore crops and agricultural methods satisfactory at one of these places would not be suitable at the other. And although the medians are approximately the same, farming is probably more precarious at Fairbury than at Crete, because the quartile deviation at the former is greater than that at the latter.[3]

[2] Quartile deviation (Q) is one-half the difference between the 75-percentile and the 25-percentile points in the given distribution.

[3] The above conclusions, of course, deal only with one of many variables, and therefore do not take into account such factors as seasonal distribution of rainfall, wind velocities, temperatures, humidity, and soil conditions.

THE RELIABILITY OF THE RECORD

The reliability of the basic data for the annual variability series of isohyetal maps depends upon several factors among which are (1) the accuracy of measurement, (2) the representativeness of the sample, and (3) the number of years the record has been kept.

Accuracy of measurement on the part of the cooperating stations must be assumed, otherwise calculation from the data would be useless. In order to check on items (2) and (3) above, special attention has been given to the data from several stations with long records. For example, Blair with a record of 64 years, has a median of 30.59 inches with a quartile deviation of 4.7 inches for the first half (32 years) of the period, and 29.35 inches with a quartile deviation of 4.3 inches for the second half (table 2 and fig. 5). Fairbury with a 58-year record, has a median of 27.78 inches with a quartile deviation of 4.3 inches for the first half of the period, and 28.08 inches with a quartile deviation of 4.4 inches for the second half (table 2 and fig. 6).

For the odd 32 years Blair had a median of 29.84 inches with a quartile deviation of 5.1 inches, and for the even 32 years a median of 29.82 inches with a quartile deviation of 4.1 inches (table 2 and fig. 7). For the odd years Fairbury had a median of 31.37 inches with a quartile deviation of 4.8 inches, and for the even years a median of 27.49 inches with a quartile deviation of 3.3 inches (table 2 and fig. 8).

A study of table 2 shows that of the 19 long-record stations only 4 had a higher median for the second half of the recorded period than for the whole period, whereas 15 had a higher median for the first half of the period than for the whole period. This table also shows that only 4 of the stations had a higher quartile deviation for the second half of the recorded period than for the whole period, whereas, during the first half of the recorded period 12 stations had a higher quartile deviation than for the whole period.

TABLE 1.—*Rainfall data for some representative stations in Nebraska*

Station	Years in record	Mean annual rainfall	Median annual rainfall	Quartile deviation	Probable error of median	Amount of rainfall or more in given percentages of the time				
						20	40	50	60	80
						Percent	*Percent*	*Percent*	*Percent*	*Percent*
Ashland	50	27.71	27.73	4.8	±0.87	33.34	29.42	27.73	25.11	21.93
Blair	64	29.51	29.81	4.4	±0.69	33.91	30.83	29.81	27.34	24.18
Crete	54	28.19	27.18	3.6	±0.62	33.42	28.19	27.18	26.24	23.24
Fairbury	58	29.35	27.96	4.1	±0.89	34.41	30.90	27.96	27.23	24.13
Franklin	45	23.33	21.74	4.1	±0.76	28.54	23.36	21.74	20.49	18.66
Genoa	58	26.59	26.20	4.0	±0.66	31.72	27.57	26.20	24.79	22.54
Hebron	49	27.59	26.95	4.4	±0.79	33.30	28.62	26.95	24.59	21.45
Lincoln	56	27.82	26.50	5.4	±0.90	34.17	28.05	26.50	25.68	22.28
Minden	56	27.39	25.65	6.4	±1.06	34.76	28.56	25.65	23.37	19.30
Nebraska City	54	31.25	29.50	4.6	±0.79	35.36	31.76	29.50	28.53	24.72
North Loup	45	24.46	23.05	3.9	±0.73	28.98	25.92	23.05	22.33	19.90
Oakdale	45	24.83	23.86	3.7	±0.69	30.91	25.78	23.86	22.73	20.84
Omaha	68	29.04	27.07	4.9	±0.75	34.98	29.54	27.07	25.73	21.64
Ravenna	55	24.65	24.08	3.6	±0.61	28.68	25.58	24.08	22.07	19.51
Red Cloud	45	23.84	23.62	5.1	±0.95	31.14	24.83	23.62	22.28	18.17
Syracuse	51	29.53	29.02	5.0	±0.88	34.63	29.71	29.02	26.77	23.62
Table Rock	45	31.08	29.55	4.8	±0.90	35.81	31.66	29.55	27.50	25.26
Tecumseh	52	30.93	30.71	4.0	±0.69	36.78	32.40	30.71	29.35	25.28
Weeping Water	55	29.57	27.17	4.8	±0.81	35.80	30.66	27.17	26.82	23.92
Beaver City	52	22.65	22.26	3.7	±0.64	27.91	23.94	22.26	20.04	17.95
Culbertson	46	19.98	19.42	2.2	±0.40	22.91	20.03	19.42	18.17	15.61
Fort Robinson	50	16.98	16.83	2.3	±0.41	19.63	17.68	16.83	15.18	12.22
Hay Springs	48	20.31	19.89	4.1	±0.76	25.16	21.95	19.89	18.69	15.98
Holdrege	45	23.65	22.11	3.9	±0.74	28.78	22.30	22.11	21.43	18.52
Kimball	45	16.23	16.10	2.6	±0.49	19.76	17.56	16.10	14.93	12.45
Lexington	44	22.50	21.99	3.5	±0.66	27.07	22.97	21.99	19.92	18.51
Newport	44	22.77	22.72	3.1	±0.59	26.37	23.71	22.72	21.29	18.67
North Platte	59	18.35	17.95	3.7	±0.59	22.47	19.10	17.95	17.12	13.19
Scottsbluff	46	15.95	15.14	3.1	±0.55	20.16	17.00	15.14	14.56	11.66
Valentine	46	19.34	18.27	3.1	±0.58	22.64	19.68	18.27	17.76	15.64

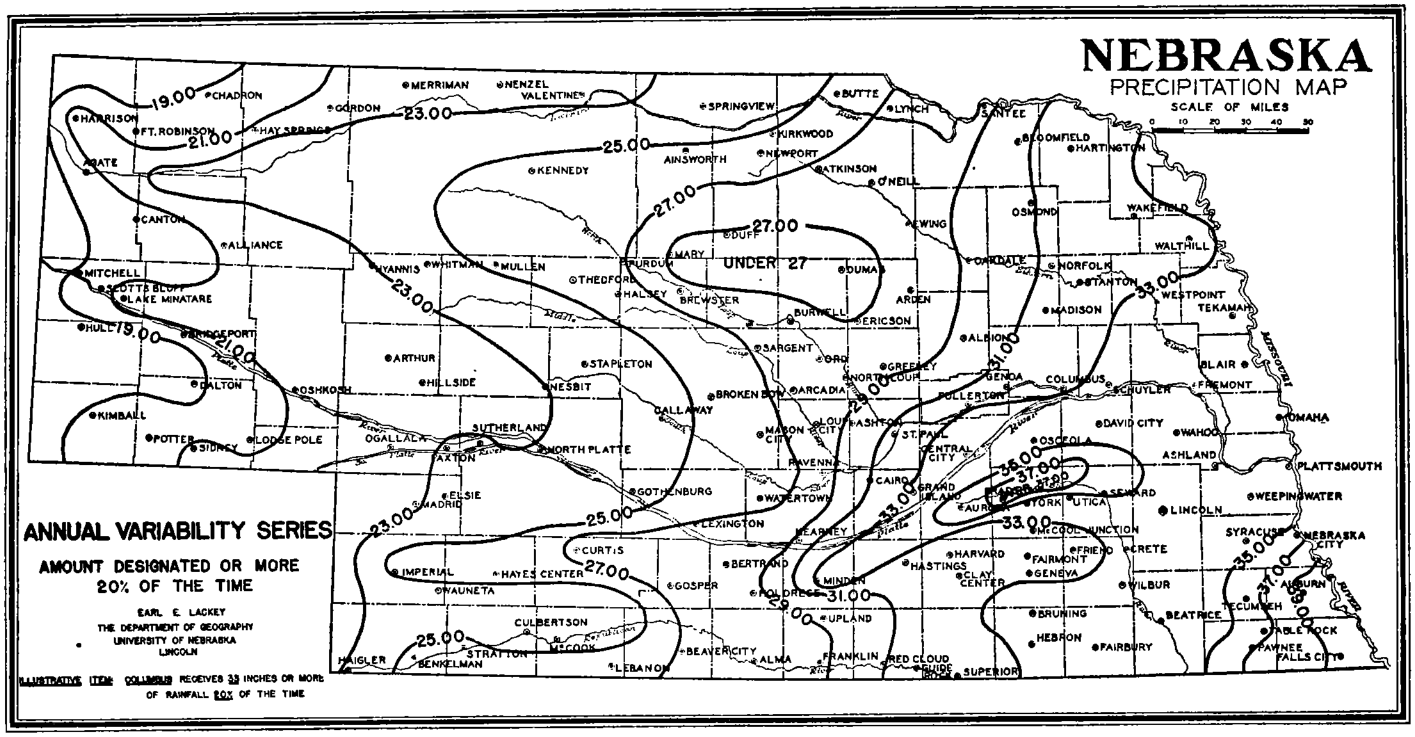

NEBRASKA
PRECIPITATION MAP
SCALE OF MILES
ANNUAL VARIABILITY SERIES
AMOUNT DESIGNATED OR MORE
20% OF THE TIME
EARL E. LACKEY
THE DEPARTMENT OF GEOGRAPHY
UNIVERSITY OF NEBRASKA
LINCOLN
ILLUSTRATIVE ITEM: COLUMBUS RECEIVES 33 INCHES OR MORE OF RAINFALL 20% OF THE TIME
UNDER 27
19.00
21.00
23.00
25.00
27.00
29.00
31.00
33.00
35.00
37.00

FIGURE 3.

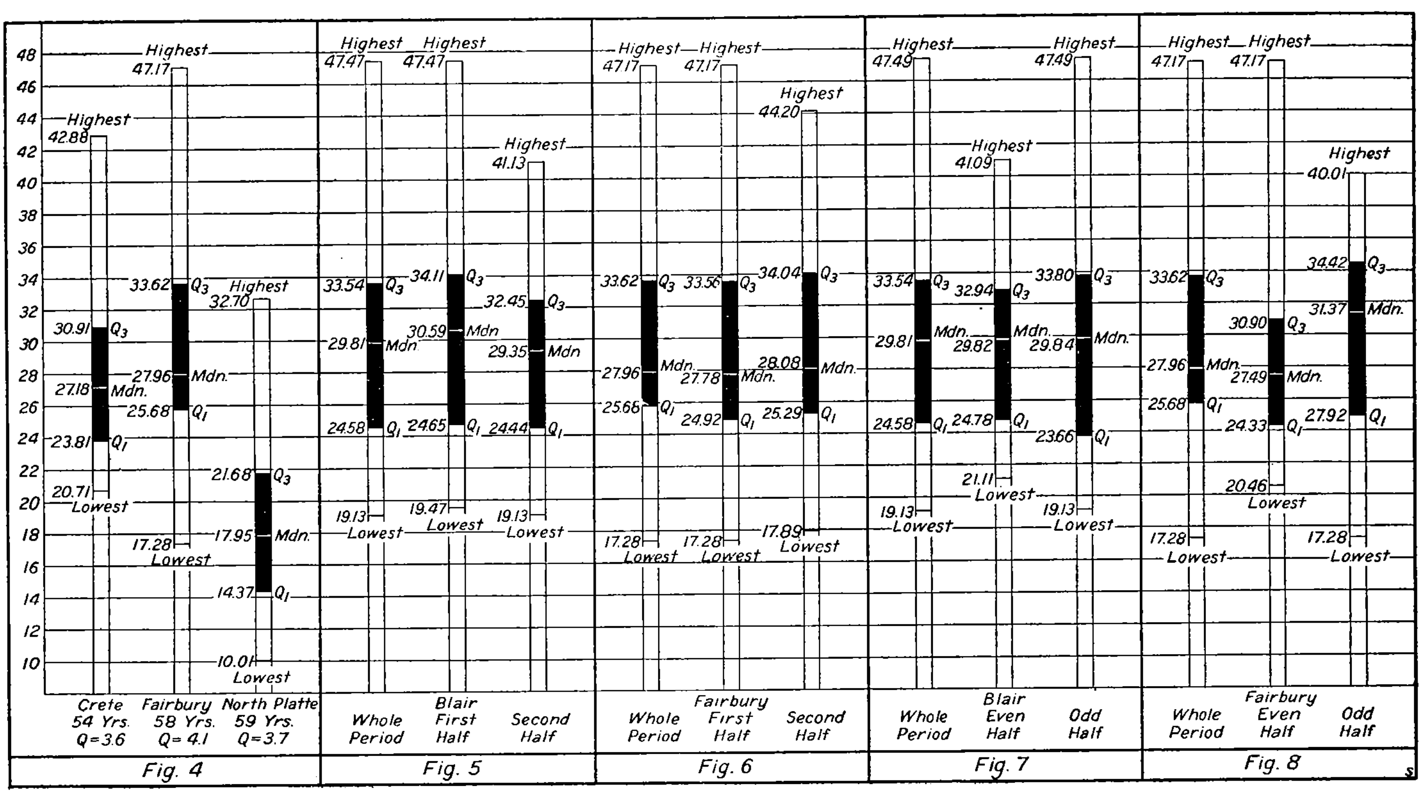

Crete 54 Yrs. Q=3.6
Fairbury 58 Yrs. Q=4.1
North Platte 59 Yrs. Q=3.7
Fig. 4
Blair: Whole Period, First Half, Second Half
Fig. 5
Fairbury: Whole Period, First Half, Second Half
Fig. 6
Blair: Whole Period, Even Half, Odd Half
Fig. 7
Fairbury: Whole Period, Even Half, Odd Half
Fig. 8
Highest
Lowest
Mdn.
Q_3
Q_1

TABLE 2

Station	Years in record	Portion of record included														
		All			First half			Second half			Even half			Odd half		
		Mean	Median	Quartile deviation	Mean	Median	Quartile deviation	Mean	Median	Quartile deviation	Mean	Median	Quartile deviation	Mean	Median	Quartile deviation
Ashland	50	27.71	27.73	4.8	30.45	30.87	4.3	24.91	23.89	3.9	28.10	26.75	4.5	27.46	27.85	4.9
Blair	64	29.51	29.81	4.4	30.01	30.59	4.7	29.08	29.35	4.3	29.54	29.82	4.1	29.55	29.84	5.1
Fairbury	58	29.35	27.96	5.6	29.17	27.78	4.3	29.42	28.08	4.4	29.45	27.49	3.3	29.14	31.37	4.8
Genoa	58	26.59	26.20	4.0	27.51	27.56	4.2	26.36	25.25	3.8	27.13	26.43	3.8	26.74	25.25	3.8
Lincoln	56	27.82	26.50	5.4	28.05	27.91	5.9	27.70	26.21	4.5	27.60	27.32	5.2	27.93	25.95	5.9
Minden	56	27.39	25.65	6.4	32.22	32.51	5.6	22.56	21.20	2.7	29.15	24.78	6.0	25.62	26.92	7.7
Nebraska City	54	31.25	29.50	4.6	30.96	29.19	5.0	31.56	29.50	4.4	32.90	28.71	4.2	29.60	30.72	4.6
North Loup	55	24.46	23.05	3.9	23.87	24.77	4.4	25.00	23.25	3.6	24.99	22.42	4.4	23.88	23.66	3.1
Omaha	68	29.04	27.07	4.9	31.97	28.98	6.5	25.99	25.83	3.8	36.63	26.99	4.3	28.66	26.89	5.5
Ravenna	55	24.65	24.08	3.6	25.87	25.58	3.4	23.39	22.42	3.8	23.66	23.76	3.9	25.60	24.26	5.2
Syracuse	52	29.53	29.02	5.0	29.39	29.03	4.4	29.65	29.04	4.2	29.82	27.60	3.8	29.22	29.18	4.9
Weeping Water	55	29.57	27.17	4.8	30.23	28.54	5.1	28.90	26.87	4.4	30.83	27.01	4.9	28.30	30.47	5.1
Beaver City	52	22.65	22.26	3.7	23.86	24.10	4.9	21.46	20.46	2.9	24.24	20.45	3.7	21.08	23.77	4.6
Culbertson	46	19.98	19.42	2.2	18.88	18.26	1.6	20.89	17.89	2.6	20.93	19.14	2.6	18.05	19.80	3.1
Fort Robinson	50	16.98	16.83	2.3	16.30	16.76	2.7	17.07	16.96	3.8	17.69	15.80	3.6	16.46	17.48	2.8
Hay Springs	52	20.31	19.89	4.1	19.47	20.59	4.2	21.12	19.55	3.8	20.84	19.89	2.0	19.75	20.84	4.4
Holdrege	44	23.65	22.11	3.9	24.87	22.72	4.4	22.43	21.40	3.2	24.93	21.36	3.3	22.36	22.37	2.8
Lexington	44	22.50	21.99	3.5	22.74	22.01	4.5	22.26	21.59	3.9	23.36	22.23	4.0	21.29	21.73	3.9
Newport	44	22.77	22.72	3.1	23.13	23.73	2.9	22.43	21.16	2.5	21.19	22.21	2.5	21.67	23.71	3.0
Averages	53	25.55	24.65	4.2	26.30	25.90	4.4	24.83	23.70	3.7	26.41	24.22	3.9	24.82	25.32	4.5

The average of the medians for the 19 stations with the long time records in table 2 is 24.65 inches with an average quartile deviation of 4.2 inches. For the first half of the periods of the same stations the average of the medians is 25.90 inches with an average quartile deviation of 4.4 inches. For the last half of the periods of these stations the average of the medians is 23.70 inches with an average quartile deviation of 3.7 inches.

Several factors may enter into the explanation of this situation among which are (1) the possibility of an actual decrease in the amount and variability of rainfall in the last quarter of a century, (2) a tendency to "boost" the rainfall record in the earlier years, and (3) the use of more refined instruments and methods for measuring and recording the data in more recent times. As to (1), the figures in table 2 seem to indicate that the average median rainfall for the last quarter of a century in Nebraska has not been as high as it was formerly. If this be true, then it follows that the medians for the long record stations run correspondingly higher than the medians for the short record stations and consequently the maps based on the data would be in error in the same degree. However, the investigator did not feel sufficiently sure of these differences to attempt to set up a correction formula, so he has drawn the isohyets on the maps strictly in conformity with the records.

It is the opinion of the writer that factors (2) and (3) also are important. When instruments were crude, capillarity, large rainfall gages and the use of rough measuring sticks each contributed to the boosting of the record. This accumulation of error together with the natural tendency in a region of rainfall deficiency to make the recording just as large as the data could possibly warrant might easily account for a boost of more than an inch in the annual record, inasmuch as such a large number of entries are necessary in making up each year's record.

When all the factors involved are taken into consideration, it is probable that 25 to 30 years furnish a record long enough upon which to base medians and quartile deviations with a fair degree of reliability.

A statistical measure of reliability of a median is the probable error of the median.[4] This measure depends upon the quartile deviation and the number of years in the record. For example, the probable error of the median for Lincoln with a median of 26.50 inches and a quartile deviation of 5.4 inches is 0.9 of an inch which signifies that if we could take a large number of 56-year samples, the chances are that 50 percent of the time the median would be 26.50 inches ±0.9 of an inch, or between 25.60 inches and 27.40 inches. Table 1 shows the probable error of the median for representative stations.

[4] Garrett, Statistics in Education, pp. 126-127, Longmans, Green and Co., New York, 926.

THE ANNUAL VARIABILITY SERIES OF RAINFALL MAPS

By the use of the five percentile points in the records of each of 109 stations in Nebraska, the investigator has constructed the five isohyetal maps of the annual variability series.

It was not thought necessary to construct more than five maps. In this study, therefore, the series includes 20, 40, 50, 60, and 80 percent maps, respectively (figures 1, 2, and 3).

On any map the isohyets pass through places having the indicated amount of rainfall or more. For example, on the 80 percent map the 19-inch isohyet passes through those places that have received 19 inches or more of rainfall 80 percent of the time. Similarly for other isohyets on this map and other maps of the series.

SOME FEATURES OF THE ANNUAL VARIABILITY SERIES OF RAINFALL MAPS

1. The map indicating median annual rainfall (50 percent map) is similar to the one showing mean annual. It presents nothing relative to variability, or departure from the normal. One learns nothing from such a map as to the dependability of the rainfall (fig. 2).

2. The variability series presented in this study takes into account the percentile distribution that has taken place 20, 40, 50, 60, and 80 percent of the time, respectively. The series shows something of the spread of rainfall as indicated by the record (figs. 1, 2, and 3).

3. A relatively high quartile deviation may be considered perilous, especially when the departure below the median is great. In such cases a deficiency in rainfall for the usual crops might be expected frequently. This holds true especially in subhumid and semiarid regions. Under such conditions we customarily say the rainfall is not dependable.

4. A relatively low quartile deviation is usually considered favorable. A small departure below median probably would not often be disastrous. In areas where the quartile deviation is low we say the rainfall is of a dependable type.

5. A knowledge of departure below the median expressed in percentage of the time should be helpful especially in subhumid and semiarid areas, or in places where there is a tendency for a wide departure from the median.

6. A knowledge of departure above median expressed in percentage of the time should be helpful especially where superabundance of rainfall may be harmful to crops or produce floods.

7. Intelligent long-time planning always takes into account as many factors as possible. Rainfall is a variable factor in Nebraska that always must be considered. The more we know about it the better planning we can do. An area with a wide rainfall variability may present fewer hazards if the percentage of variability is known and considered when plans for the future are being made. This variability series of rainfall maps of Nebraska may offer some possibilities in this connection that previously could not so well be taken into account.

THE HURRICANE WARNING SERVICE AND ITS REORGANIZATION

By EDGAR B. CALVERT

[Weather Bureau, Washington, April 1935]

Tropical cyclones are the meteorological monsters of the sea. No other type of ocean storm approaches them in violence and destructiveness, nor in the persistency with which they maintain their form and force. It is a rare thing for one of them that has fully developed to dissolve and disappear over water surfaces in the Tropics. With few exceptions they continue as violent storms until they strike land or pass out of the tropics. They are called hurricanes when they occur in the Atlantic Ocean, Gulf of Mexico, Caribbean Sea, and the Pacific Ocean off the coast of Central America and Mexico; they are known as "typhoons" in the China Sea; "baguios" in the water area of the Philippines and "cyclones" in the Bay of Bengal and other portions of the Indian Ocean. By whatever name they are known and wherever they occur they strike terror into the hearts of seamen and of people who reside along the low-lying shores subject to their visitation.

No one person or organization can surely be credited with being the first to engage in a systematic forecasting program for the purpose of giving warning of the approach of hurricanes. William Reid began his studies of them when on duty on the island of Barbados in 1831. His work published in 1838 is still held in esteem as a book of reference. He studied hurricanes, plotted their courses, and formulated his "law of storms", including rules for mariners to maneuver so as to avoid their centers; and in 1847 he established the earliest system of displaying warnings when the approach of a storm was indicated by the barometer.

The credit for the next warnings is probably due to Father Benito Viñes, who for many years was associated with Belen College at Habana, Cuba. It is known that in 1870, when Father Viñes became director of the college, he began to grapple with the problem of forewarning the people of the advent of hurricanes which threatened them. Before that time the inhabitants of Cuba were accustomed to hear of these phenomena only upon their near approach. This was the same year that the United States Congress made appropriations for organizing a national meteorological service, control of which was vested in the Signal Corps of the Army (later transferred to the Agricultural Department as the Weather Bureau). The Signal Service was scarcely in position to issue hurricane warnings until August 6, 1873. On that date arrangements for securing daily weather reports by cable from Cuba and other islands of the West Indies went into effect with receipt of observations from Habana. Daily reports from Kingston began September 18, and from Santiago de Cuba, on September 29 of the same year. Plans for obtaining reports from Puerto Rico, Guadeloupe, and Barbados did not materialize that year as was expected.

The meteorological service of the Signal Corps did not start functioning until 1870, but almost from the beginning the need for issuing warnings of hurricanes to the people along the southern coasts of the United States was recognized; also that this could be accomplished only by obtaining current observations from islands in the West Indies. Plans for obtaining such observations were discussed in the reports of the Chief Signal Officer for the fiscal years 1872, 1873, and 1874.

Father Viñes had nearly 3 years' start on the Signal Service in organizing his hurricane warning service. According to one of his commentators (Rev. Walter M. Drum, S. J.), the earliest authenticated date on which he issued a warning was September 11, 1875, but it seems likely that he did so prior to that time. There, too, is uncertainty as to the date of the first hurricane warning issued by the Signal Corps. Father Viñes is generally conceded to be the first meteorologist to forecast hurricanes from observations of the upper as well as the lower clouds; also, he was the first to announce that both the place of formation and the direction of movement of hurricanes change as the season advances. The August 1873 issue of the MONTHLY WEATHER REVIEW refers to a forecast issued on August 23, 1873, of stormy weather for the New England and Middle Atlantic coasts "with cautionary signals at Cape May, New York, and New London." This article contains a statement to the effect that the storm was of tropical origin, that it was by far the worst one since the establishment of the Signal Corps and that it "did not occur within the limits of our stations." It is a safe deduction that August 23, 1873, was the date of the first warning issued in connection with a storm of tropical origin but it would not be proper to claim that it was a hurricane warning because the storm was extratropical when the warnings were put out.

Father Viñes is justly placed in the front rank of those who have contributed to our knowledge of tropical storms and have been untiring in their efforts to develop means for forecasting them.

Father Viñes' hurricane forecasting studies were in four directions: First, to find some sign or group of signs that would invariably prove the existence of a cyclone while it was yet at a great distance from the observer; second, to get bearings in regard to the whirlwind, i. e., to determine what part of the horizon it was coming from; third, to locate the trajectory or curve along which the cyclone would move, and to do this in